# ADEPT - A Mechanically Deployable Entry System Technology in Development at NASA

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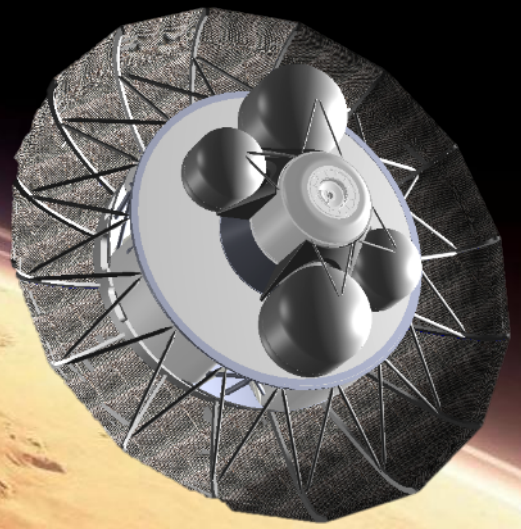

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ESTEC, Noordwijk, Netherlands

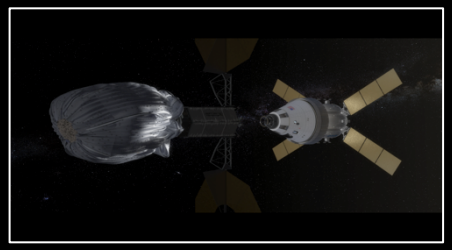
# Acknowledgements


- Realizing the dream requires dedication by a large community of people and leadership along the way.
  - EDL experts at NASA Centers (Ames, Langley, Johnson, Goddard), JPL and APL
  - Funding support from NASA HQ and NASA Ames (Center Investment funds).
  - Facilities – Arc-jets and Wind-tunnels at Ames and JSC
  - Technology Partners – Bally Ribbon Mill and Thin Red Line

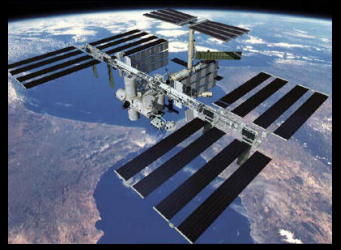
- ADEPT Project Leadership:
  - Peter Gage, James Arnold, Dinesh Prabhu, Keith Peterson, Ken Hamm and numerous others at Ames and other NASA Centers.

# The 21st Century – Will It be as Great as the 20th Century for Human Exploration?

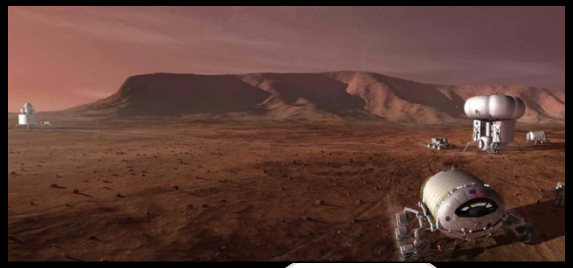
Shuttle Last Flight
July 8, 2011



Asteroid Redirect
~2020 ?



End of Station
~2025+ ?



Human Mars Mission ~2035 ?

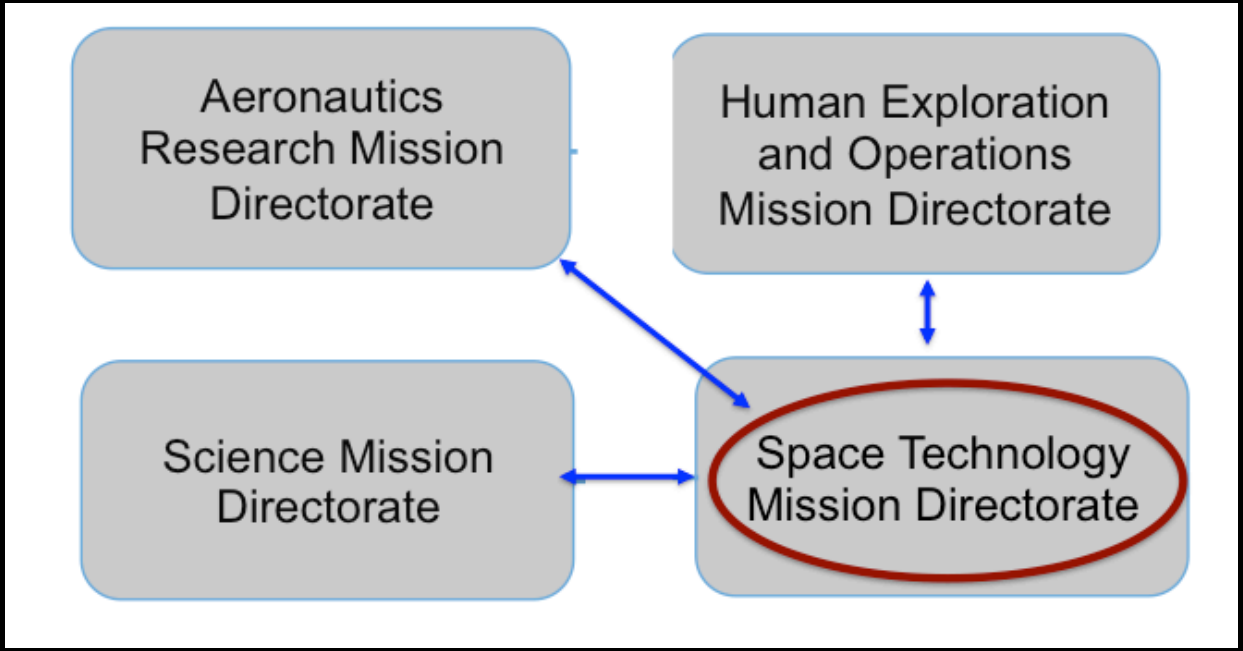
MERs
Jan 4, 2004
Jan 25, 2004

Phoenix
May 25, 2008

Curiosity/?
2012/2020

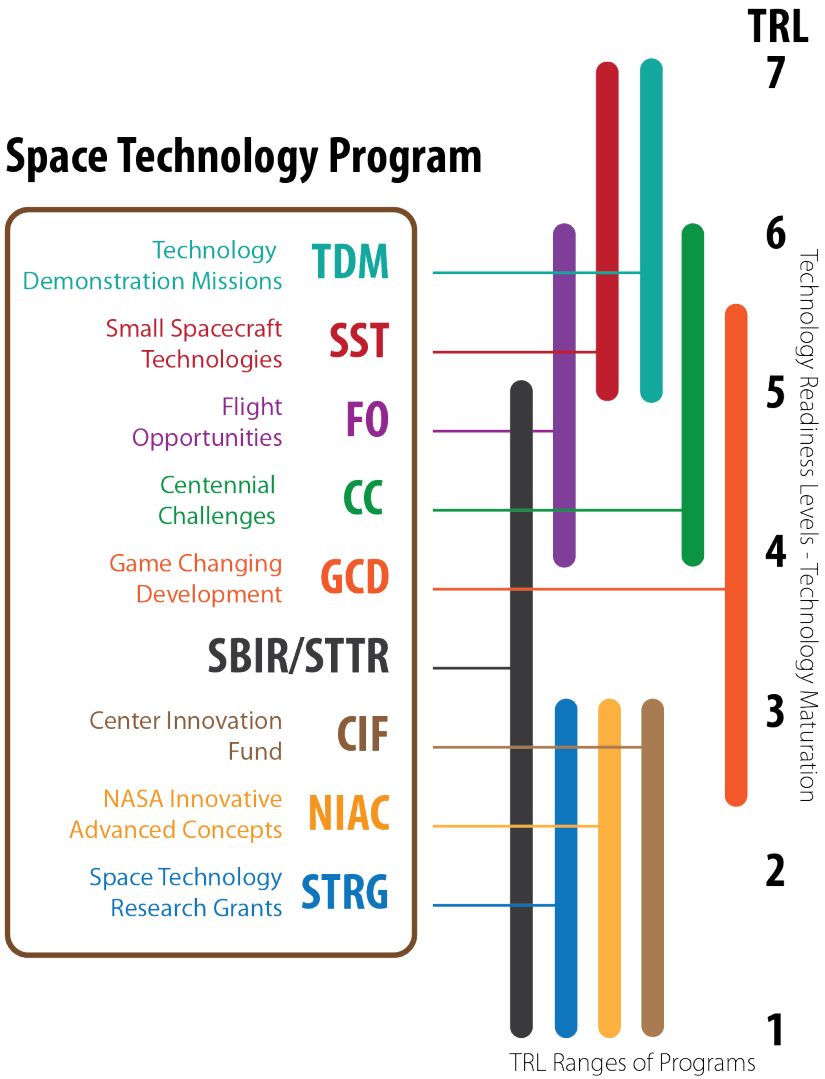
MSR? Precursor to Human?

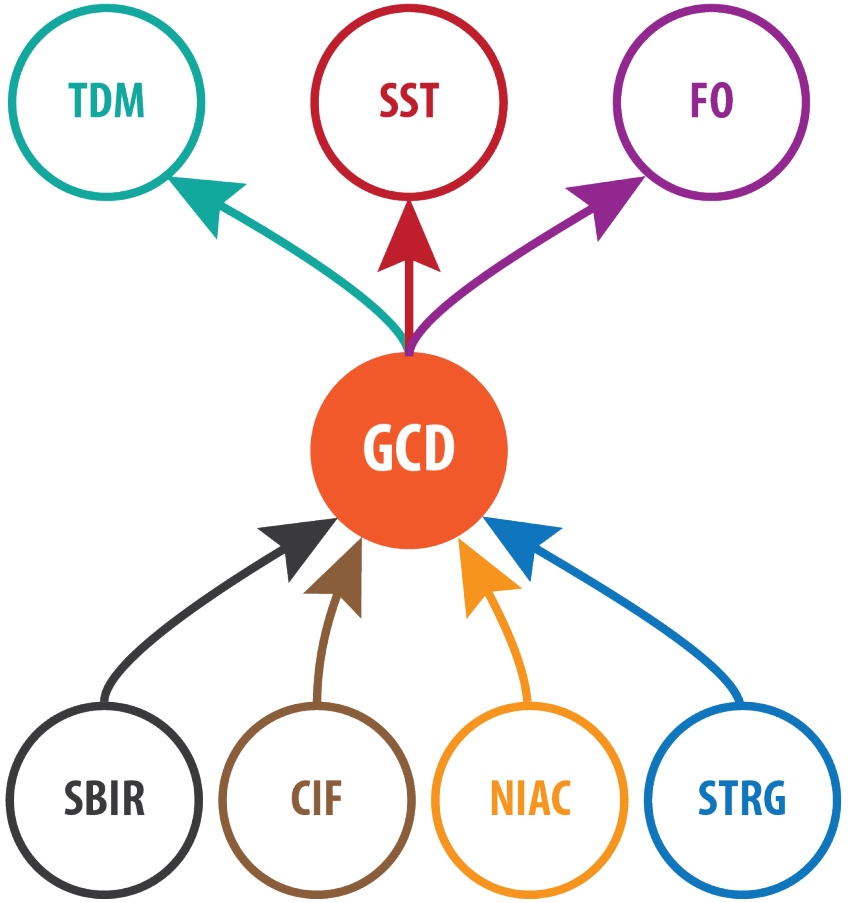
# NASA TODAY
# TECHNOLOGY INVESTMENTS FOR THE FUTURE




- Interaction and Collaboration between Mission Directorate
  - Technology Roadmap and Investment Prioritization
  - NRC Decadal Committee Recommended Missions

# NASA TODAY: STMD
# TECHNOLOGY INVESTMENT OPPORTUNITIES



# HUMAN MISSION TO MARS

Technical challenges - Getting there and coming back, safely.

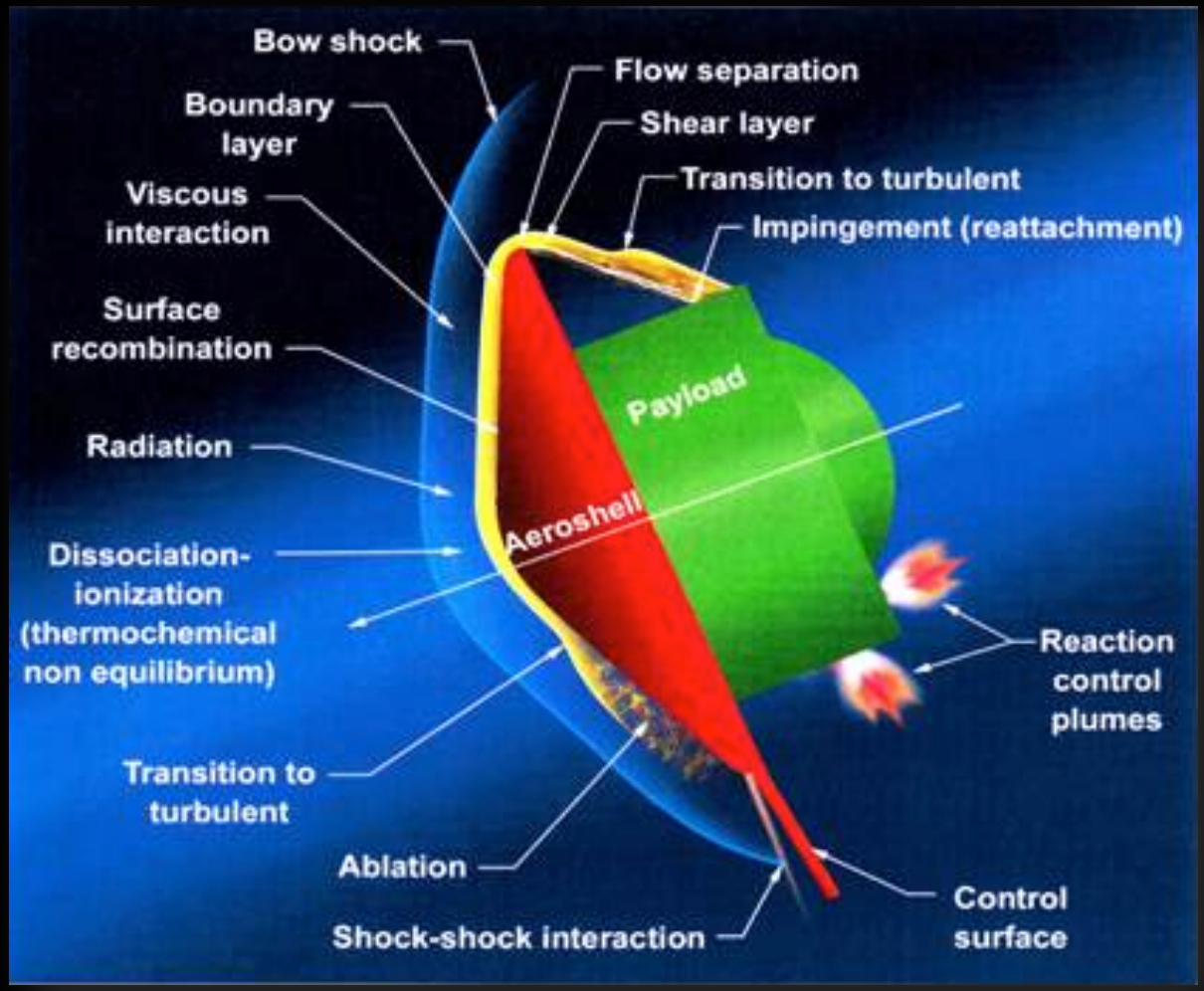
- Getting to the surface of Mars safely and with precision
  - Humans are fragile – EDL has to be tailored for human survival
  - Human missions require
    - ~(20mT - 40 mT) of landed mass per launch
    - MSL landed mass of 899 kg required a launch mass of 531,00 kg
- Getting back to Earth from Mars
  - Orion derived capsule may need upgrade
    - Return velocity likely to be higher

NASA, specifically NASA Ames, is working on both the challenges

- Mars Entry, Descent and Landing concept development
- Ablative Thermal Protection System For Earth Return

# ENTRY PHYSICS

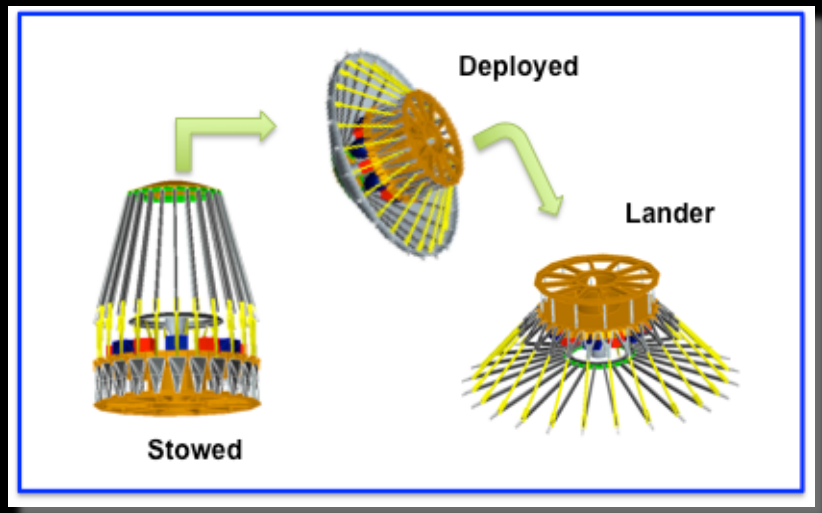
- Complex and our ability to predict has improved considerably
  - Computational simulations, ground test facilities, and flight data

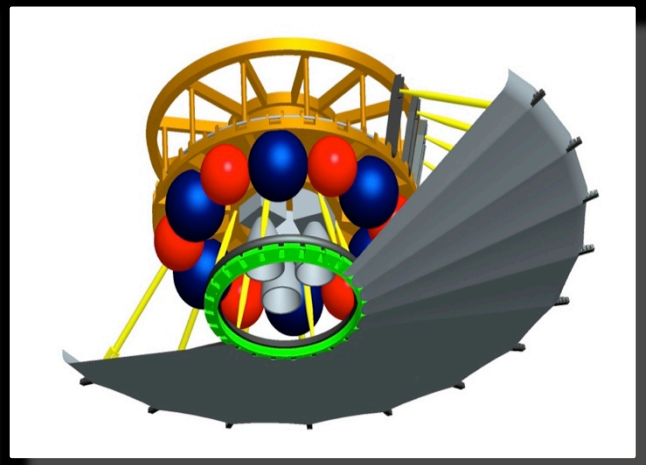


# ADAPTIVE DEPLOYABLE ENTRY AND PLACEMENT TECHNOLOGY (ADEPT- 2011)

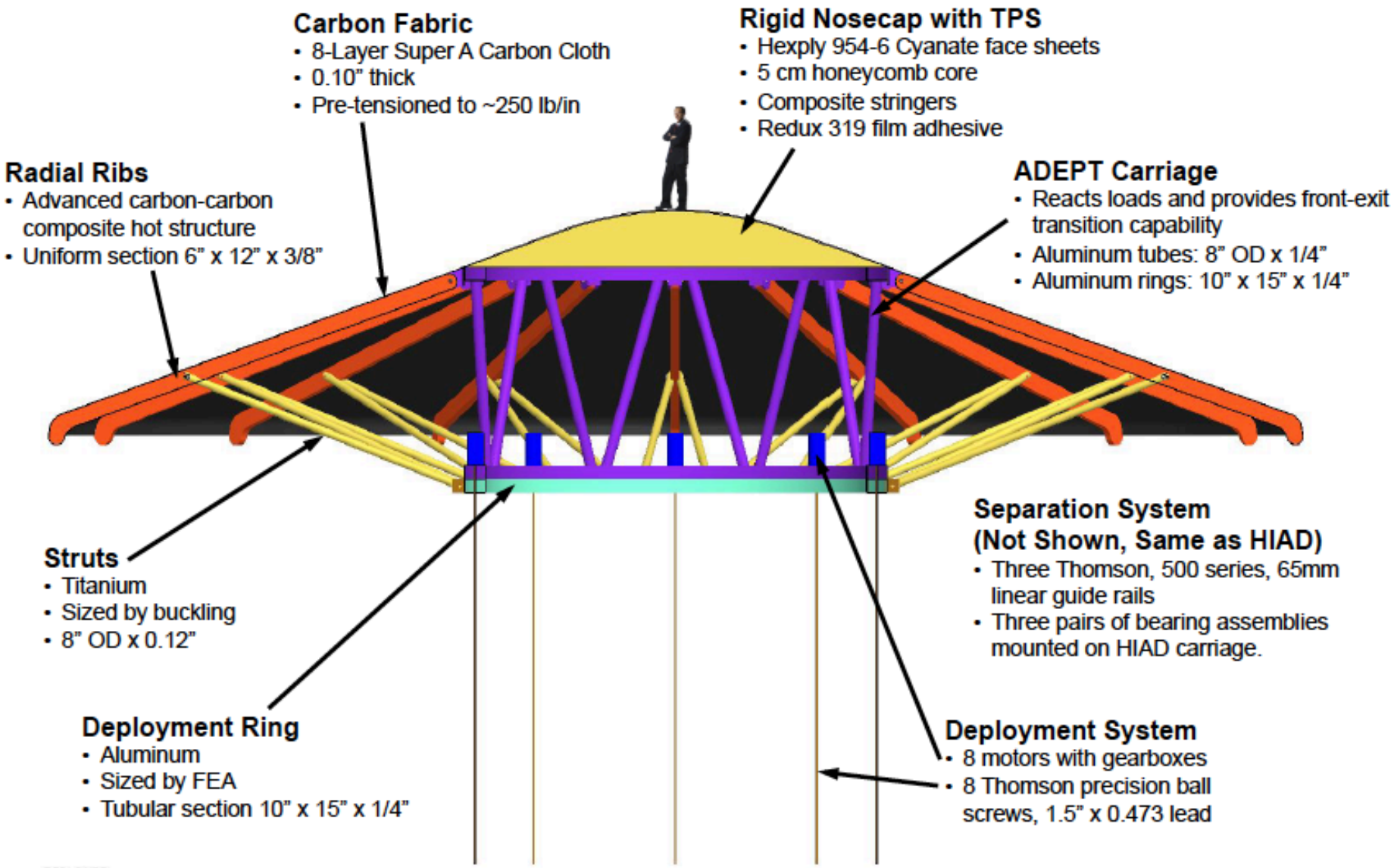
**The mechanically deployable and transformable concept is similar to an umbrella but more complex functionally.**

- Deployable thermal protection and aerodynamic load bearing fabric system;
- A deployable structure behind the that reacts to the primary aerodynamic load and provides a simple interface to the delivered payload;
- A self-contained deployment system;
- A primary gimbal design for pivoting of the aeroshell and thereby providing GN&C.
- An ejectable nose heat shield for the retro-propulsion system function;
- A design that transforms the aeroshell into a lander configuration



# ADEPT FOR HUMAN MARS MISSIONS

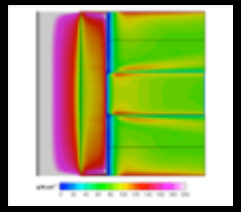


# Project Background

- ADEPT FY12-FY13
  - STMD Game Changing Development Program
  - Focus on 6m Venus DRM (Delivery of 1000kg lander with peak decel < 30 g's)
  - Carbon fabric arc-jet tested 100-240 W/cm$^2$.
  - Successful demonstration of 2m Ground Test Article
- ADEPT FY14
  - Demonstration carbon-fabric stitched joint
  - Project re-plan to 1m scale
    - Potential for 'cubesat class' secondary payload mission infusion
    - Cost effective approach for key system-level demonstrations
- ADEPT FY15/FY16
  - Focus on **0.7m aero-loads wind tunnel test** & **0.35m SPRITE pathfinder arcjet test**
  - Development efforts - 0.7m sounding rocket flight

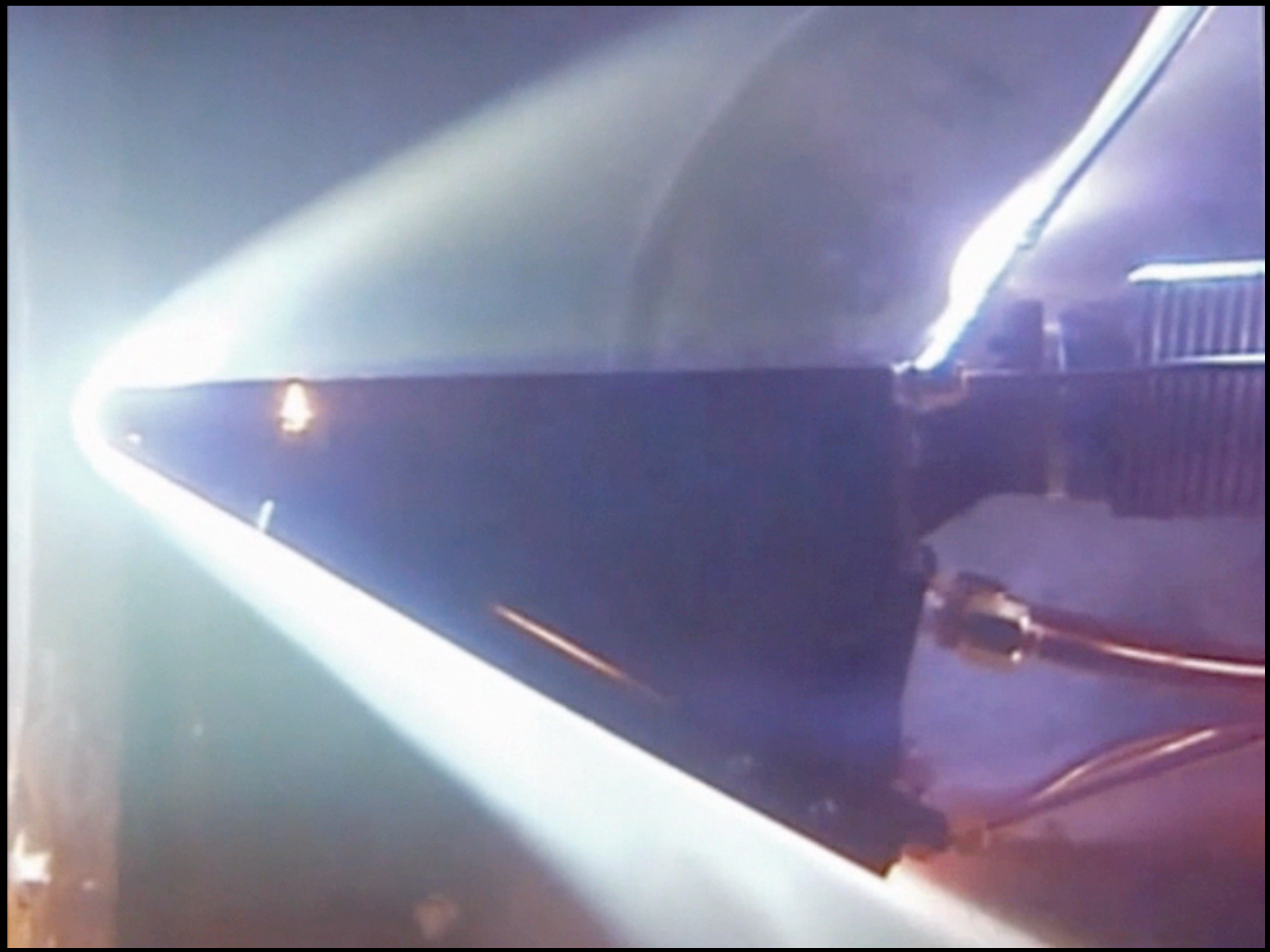
*Carbon fabric arcjet testing (2012)*

*2 m Ground Test Article (2013)*

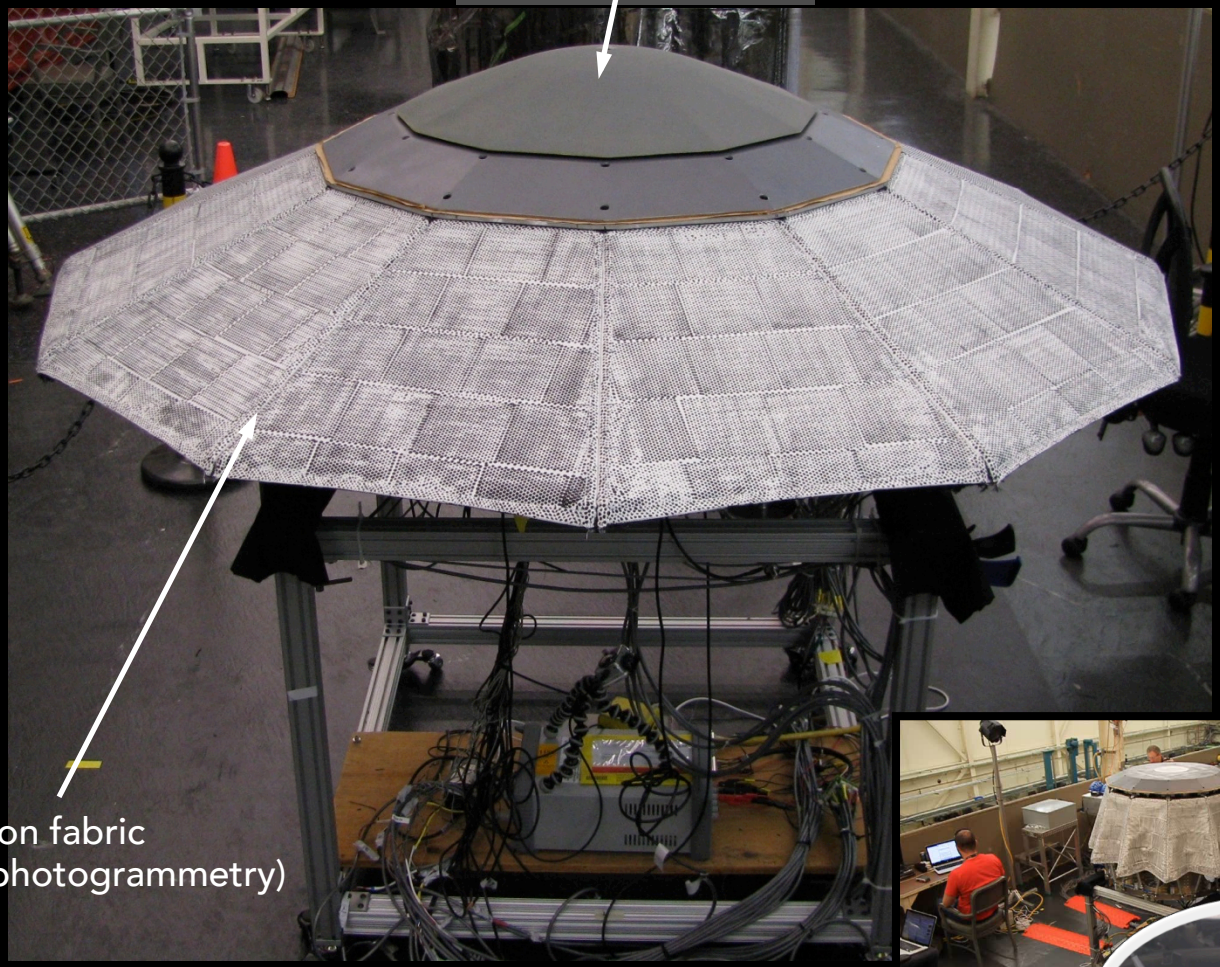


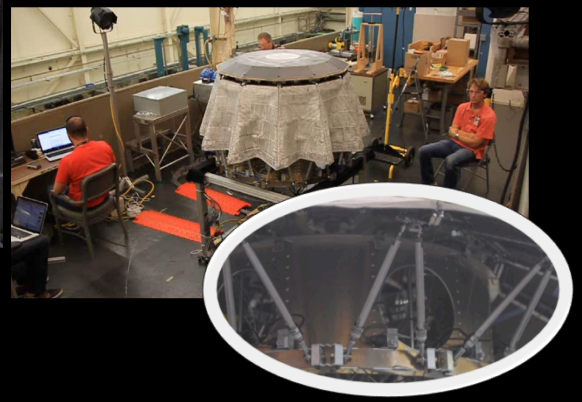
*Fabric Joint Design Testing (2014)*

# CARBON FABRIC TESTING AT VENUS RELEVANT CONDITIONS

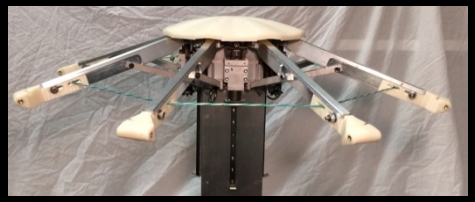


# 2m GROUND TEST ARTICLE DESIGN, BUILD AND TESTING

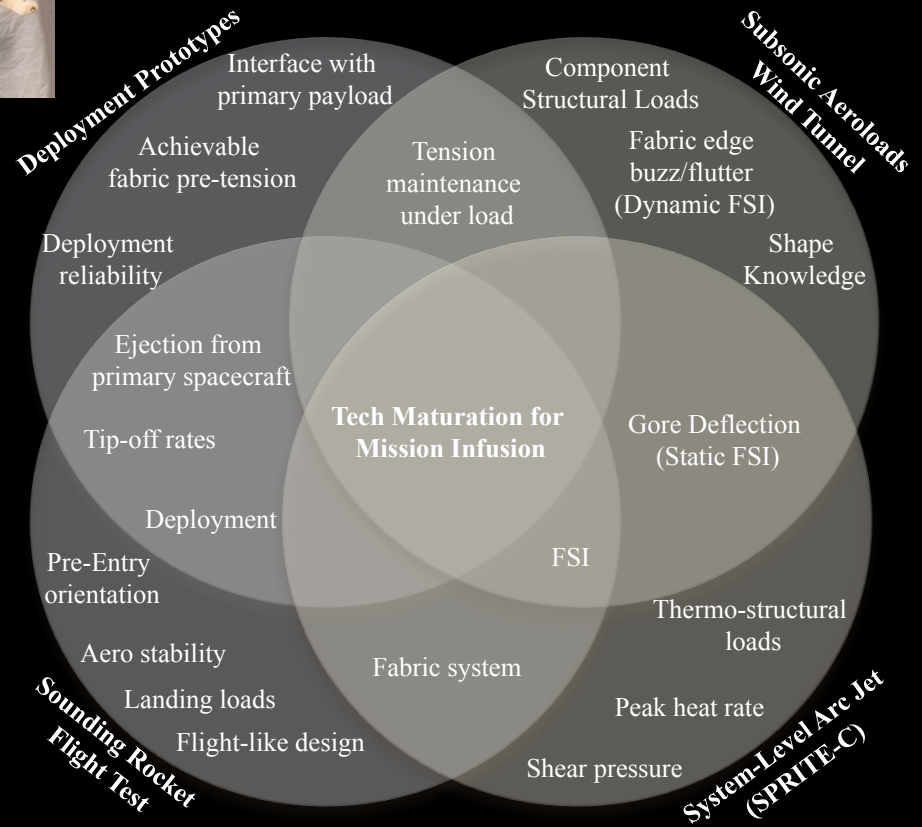


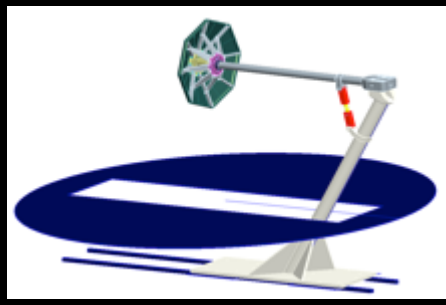



# 1m ADEPT Technology Maturation Approach FY15-16



**Deployment Prototype Demonstration (FY15)**

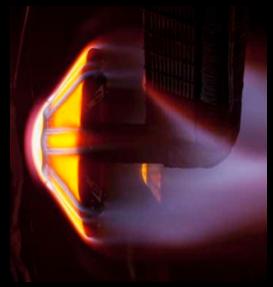


**7x10 Wind-tunnel Aeroloads test (FY15)**

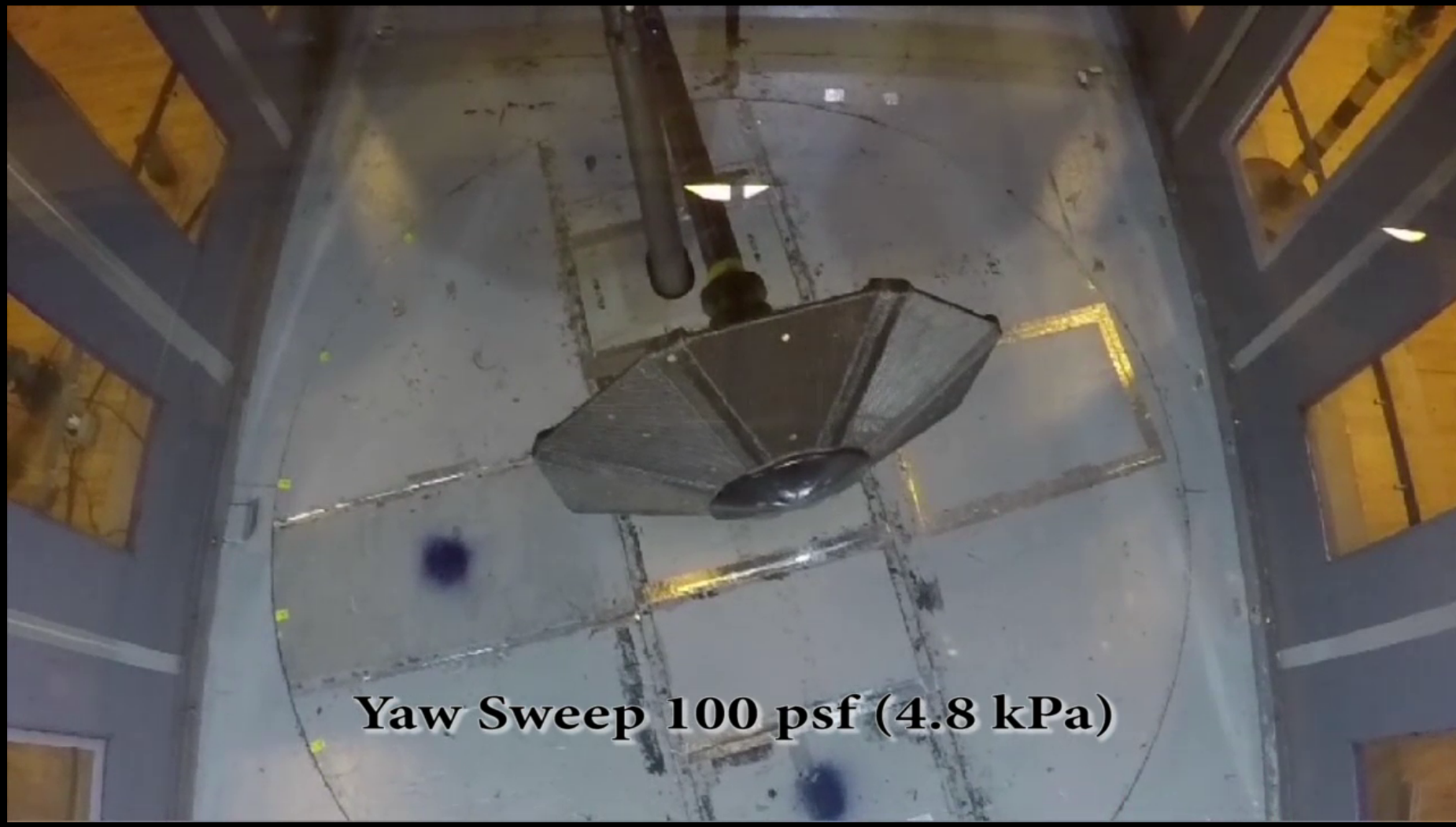
**Sounding Rocket Flight Test**

**SPRITE C System level Arc-jet testing**



Each test campaign provides system knowledge in more than one system attribute, and many system attributes are explored by more than one test.

# VIDEO HIGHLIGHTS FROM 7X10 TEST



# SPRITE-C Pathfinder Test Article #2 Test Video (1st Pulse 40s duration)

IHF 301
21" Nozzle

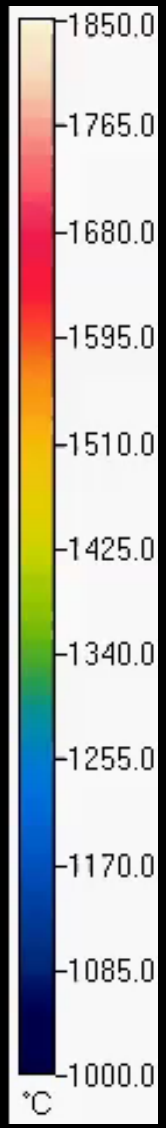
East Sting: SPRITE-C #1

Overhead Sting: Slug_Cal_102mm_Hemi_OH

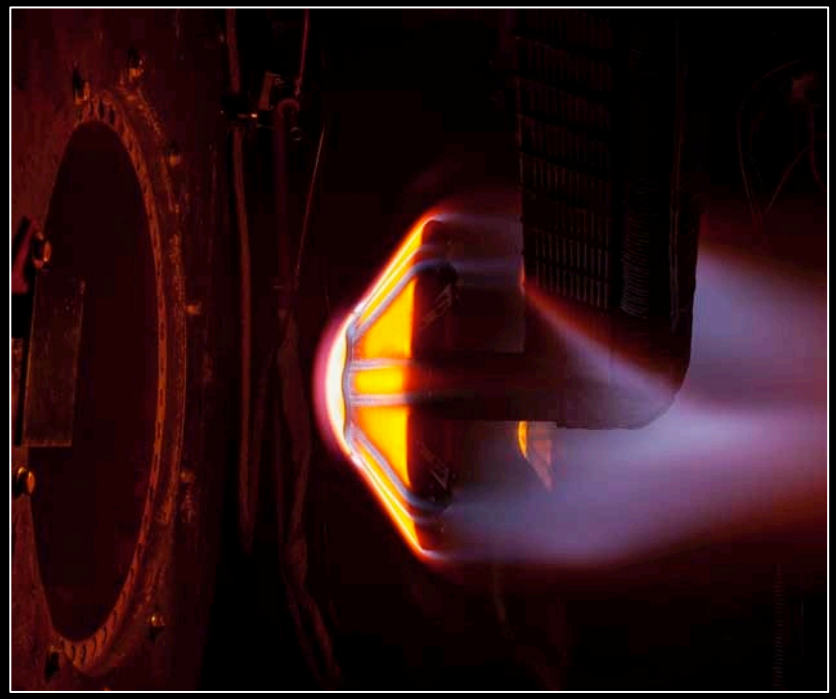
West Sting: SPRITE-C #2

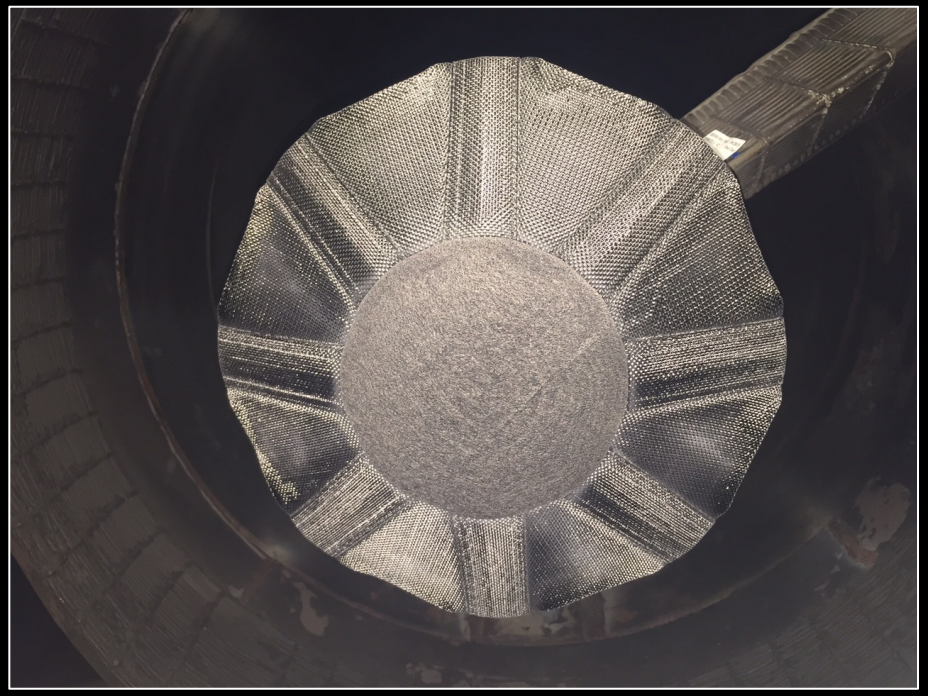
Run: 001
Date: 09/28/2015

# Test Article C1 IR Video



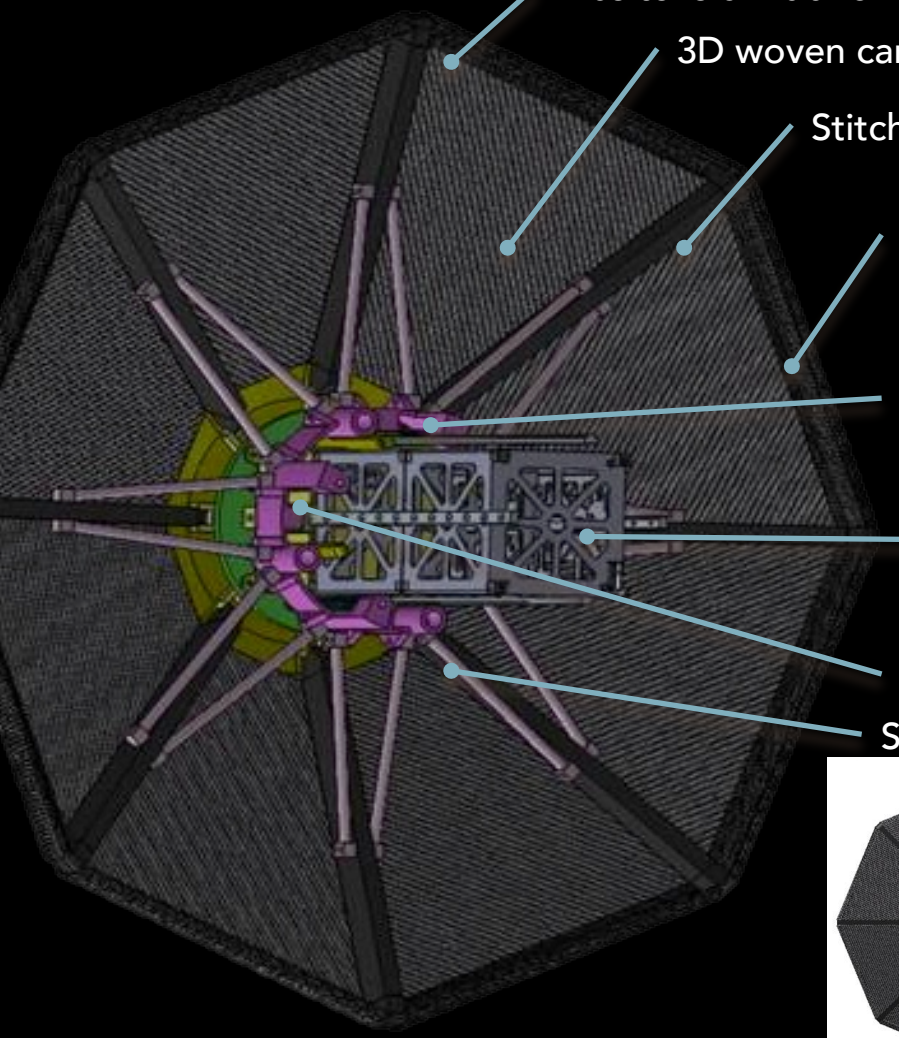
# SPRITE-C Pathfinder Post-Test Image





Dual heat pulse – 7.5 kJ/cm$^2$ total stagnation point heat load

# SUB 1m NANO-ADEPT



Ribs tension fabric with pockets at tips (like an umbrella)

3D woven carbon fabric sized for mission

Stitched and resin-infused seams

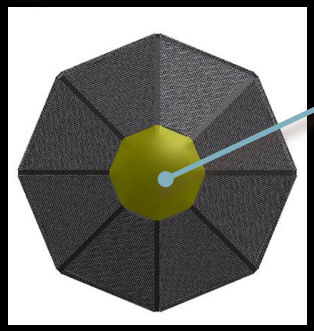
Shoulder stitching treatments

Two phase spring-deployment system
(1- high displacement, 2- high tension)

Payload area (2U shown for example)

Avionics unit (IMU, GPS, solid memory, power)

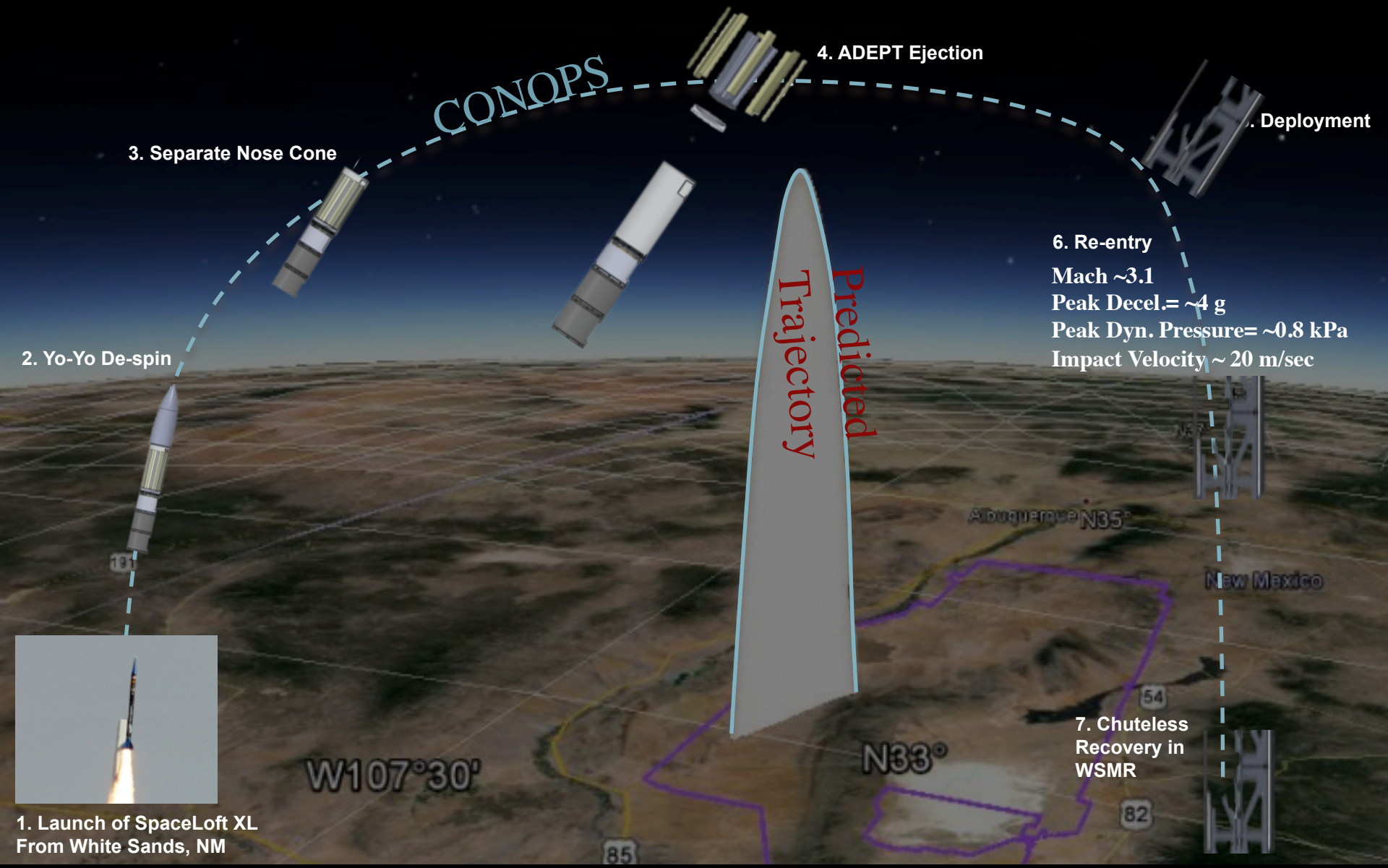
Struts



Conformal TPS Nosecap

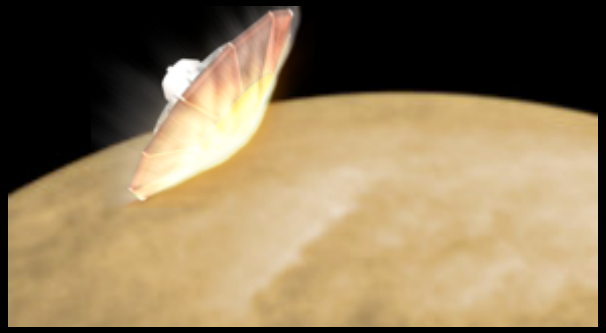
*Other mission-specific hardware not shown: antennae, parachute*

# SOUNDING ROCKET FLIGHT TEST (CY'15)



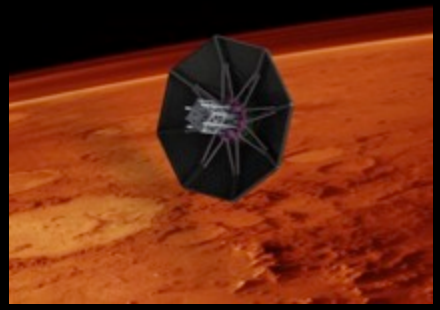
# 1m ADEPT Mission Pull (Discovery class)

## Venus



Science Pull:
- Delivery of In-situ atmosphere science instruments.
- Achieve low deceleration loads for sensitive instruments

## Mars

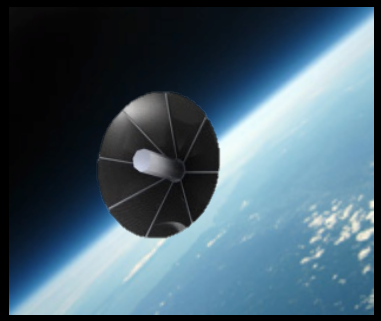


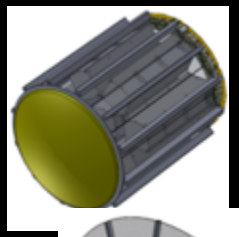
Science Pull:
- Global distribution, low cost
- Numerous landers

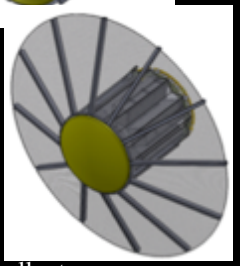
Dandelander (Malin SSS):
Cubesat distributed surface network concept

## Earth

LEO Return: Secondary on Upper Stage, ISS Downmass or free-flyer on Super Strypi class LV







-De-orbit Capability
-22 N thruster incorporated with green propellant
-6 ea, 3U slots for subsystems or payloads

## Titan

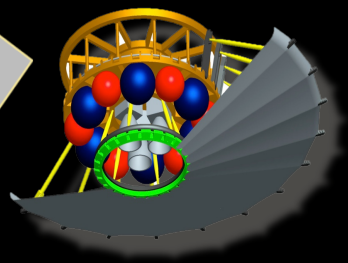
- Lifting ADEPT configuration allows aerocapture at Titan, effective thermal control with open-back configuration

# A SCALABLE ADEPT EDL ARCHITECTURE
# MISSION INFUSION OPPORTUNITIES

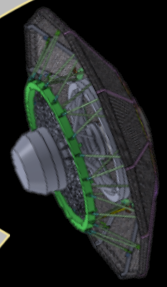
Human Mars (> 2035)

(15m – 23m)

Large Scale
Lifting Concept
Flight Demos
( > FY'2026)



ADEPT Lifting
(FY'16 – FY'18)



(6m – 15 m)

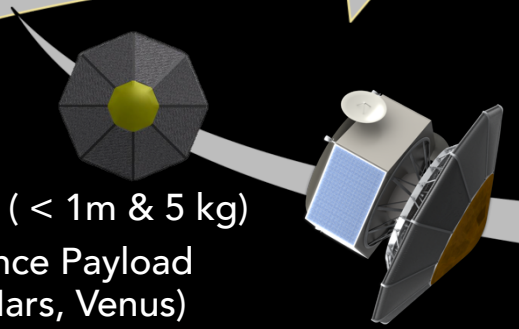
Venus Lifting (2018+)

-Aerocapture

Mars Robotic Lifting
Precursor (2020+)

ADEPT Full-Scale
Demonstrator Project
FY'2014-17

ADEPT Project
TRL Maturation
FY'12 – FY'13



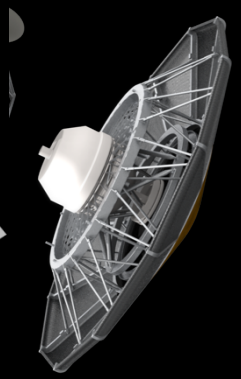
Nano-ADEPT ( < 1m & 5 kg)

Small Science Payload
(Earth, Mars, Venus)

Human/ Heavy Mass
Mars Mission and
Design Studies
FY'11

Ballistic –Venus, 6m

VISE Lander (~2017)



Ballistic Robotic Mars, 10m
(2020+)

Total Global surface access
No supersonic chutes

# SUMMARY REMARKS

- Mars has been and continues to be both an exciting and a challenging place to explore
  - We have reached the limit of EDL technology with MSL
  - Landing large payloads and human at Mars is a grand challenge
    - Combination of innovation and new technologies needed

- Mechanically deployable entry system, ADEPT, is a game changing concept that has the potential
  - Within 5 years, retrieving small-satellites from around earth orbit and send small payload to Mars and Venus.
  - Within a decade, enable cost effective, in-situ missions to robotic science exploration
  - In the longer term, the concept and the robotic experiences at earth, Venus and Mars can enable Human Mars missions

Thank you

Questions?